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ELECTRONIC SURGE PROTECTION EQUIPMENT

Relationship of Grounding and Bonding to the Effectiveness of Lightning Protection Devices

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RELATIONSHIP OF GROUNDING AND BONDING TO THE EFFECTIVENESS OF LIGHTNING PROTECTION DEVICES

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ABSTRACT

The location and manner of connection is critically related to the effectiveness of a lightning protection device. Hazardous potentials can develop between nominally grounded objects when the grounding conductor from one of them is conducting steep wavefront current. It is shown that by reducing the length of connections, either directly or by parallel paths, plus appropriate bonding, the full effectiveness of lightning protection devices can be achieved.

INTRODUCTION

The system effectiveness of a lightning protection device can be seriously impaired by poor grounding and bonding practices regardless of how well the device has been designed or the care with which it was selected for the application. Actual installations vary considerably in physical size; consequently, arrester leads and grounding conductors frequently assume significant dimensions. This is especially true of grounding conductors which unavoidably may be several feet in length. Because of the impedance of these connections, surge voltages appearing at equipment terminals may be substantially higher than those at the arrester terminals. The same is also true of communication protectors. This situation is frequently aggravated by failure of wiremen to minimize the length of such leads by running them in the most direct manner practicable.

Inductive voltages developed in grounding conductors stress equipment insulation with respect to ground and may present a shock hazard. The principles discussed in this paper are already documented but a review seems justified because they are frequently overlooked in practice.

CRITICAL ASPECTS OF CIRCUIT CONNECTIONS

The sparkover voltage of a communications protector or power arrester is often presumed to be the protection level that it will afford equipment by simply connecting it to the circuit. This is not necessarily true because of the inductive voltages that are produced by steep wavefront surges in the leads required to connect and ground such devices. If a protection device is connected directly to or in proximity to the equipment requiring protection, transverse voltage at the equipment (tip to ring or phase to neutral) is unlikely to exceed the sparkover of the device. The discharge voltage of a well designed protector or arrester does not ordinarily exceed its sparkover value when properly selected for the application. However, voltage to ground frequently exceeds that appearing at the terminals of the protection device because the potential drop in the grounding conductor adds to the discharge voltage of the device. In situations involving other than dc or low frequency currents, inductive voltages appear in grounding and bonding conductors of much

higher magnitudes than the resistive components.

INDUCTIVE VOLTAGES IN GROUNDING CONDUCTORS

The sketch in Fig. 1 offers a simple illustration of the basic concepts involved. It is assumed that lightning surge current enters a radio cabinet over the outer conductor of a coaxial line. An inductive voltage will develop in the grounding conductor between a and b. This voltage, V_L, also appears between the radio cabinet and an adjacent one. To obtain an approximation of this voltage, some representative values will be assumed.

1. Total stroke current to tower = 50 kA, about one third of which (16 kA) enters the station over the line.

2. Time to crest of current in line is 2 microseconds.

3. Length of grounding conductor, ℓ, from a to b = 25 feet.

4. Type of conductor — #6 AWG copper, diameter, d = 0.162".

The self-inductance of a conductor may be approximated with the following expression.(1)

$$L \simeq 0.061 \ell \; (\log_e \frac{4\ell}{d} - 0.95)$$

microhenrys where:

ℓ = length of conductor

d = diameter of conductor

All units are in feet

Using the assumed values:

$$L = 0.061\,(25)\,(\log_e \frac{100}{0.0135} - 0.95)$$

$$= 12.2 \times 10^{-6} \text{ henrys.}$$

The maximum inductive voltage, V_L, results from the rapid rate of change during the period of the current wavefront.

$$V \simeq L \frac{di}{dt} \simeq 12.2 \times 10^{-6} \left(\frac{8000}{10^{-6}} \right)$$

$$V_L \simeq 97.5 \text{ kV}$$

This is not an exceptionally high voltage for the type of situation under discussion. Arc distances ranging from several inches to a few feet have been observed in radio stations before remedial measures were taken.

The following useful facts become apparent through consideration of the problem:

1. Increasing the diameter of a conductor does not significantly reduce its self-inductance, e.g., doubling the diameter reduces L by a mere 9%.

2. Reducing the length of a conductor is the most effective way to reduce its self-inductance. In this problem, reducing the length of the conductor 50% gives a reduction in L of about 55%.

3. Paralleling conductors(1) is a reasonably effective way to reduce self-inductance of a path, e.g., connecting another #6 AWG conductor in parallel with the existing ground lead at an average separation of 3 feet will reduce L by about 37%.

4. Resistance of the grounding electrode does not contribute to the voltage, V_L, appearing between the cabinets.

To mitigate the hazards in this situation obviously requires something different than the popular panacea of increasing conductor size and reducing electrode resistance. The effective measure is a short, direct bond between the two cabinets. This will eliminate the shock hazard between the two cabinets and in addition it will substantially reduce inductive voltage in the grounding leads since there are now two conductors in parallel.

APPLICATION OF BONDING MEASURES

Judicious bonding is very frequently required to enable protection devices to achieve their full effectiveness. The following situations were selected to illustrate this point.

Fig. 2 shows the protection sometimes provided for a TV receiver. Protection is not very often provided but when it is, an isolated ground rod is frequently used for the grounding electrode. Again, we have a case of failure to provide common grounding. A simple bond between the grounding lead from the antenna mast and protector to the metallic water pipe would greatly reduce surge voltage that can appear at the interface between video and power circuitry. The improved protection achieved with this bond may not prevent component failure in the case of a direct lightning stroke to the antenna, but it will greatly reduce shock and fire hazards.

The extent to which bonding is employed in a well engineered microwave installation is shown in Fig. 3. The bonding conductors indicated on this layout are supplemented in the actual installation by many fortuitous paths provided by metallic conduits, power circuit grounding conductors, cable frames, etc. Experience has proven that such precautions are essential to control side flashing and make the area safe for personnel.

A problem that can involve a variety of ac powered communication equipment is presented in Fig. 4. The physical size of an installation often makes it impossible to locate the communications grounding connection close to the power neutral grounding point. In practice, an installer has only limited discretion as to where the customer's equipment is to be placed. Both facilities will be grounded to the same electrode (metallic water pipe) but in some of the larger installations, the distance between connections (b to d in Fig. 4) may be in the order of several hundred feet. This of course aggravates the problem of surge overvoltages appearing at the interface between the power supply and transistor circuitry. Protection measures involve the addition of the protection devices indicated in the figure, namely, a secondary type arrester on the power service conductors and protectors with sneak current fuses at the input terminals to the communication equipment. Also, a short direct bond must be placed between the two equipment cabinets. The surge withstand capability of electronic equipment is such that it may not coordinate directly at the levels required to spark over conventional protectors and arresters, in which case supplemental protection must be employed, frequently in the form of a low voltage solid state device.

SUMMARY

Designers of equipment must recognize that field installation people have very limited control over operating environment and practical considerations frequently necessitate departure from ideal

grounding arrangements. Much can be done, however, to assist the performance of protection devices through the use of good bonding techniques. When establishing equipment design criteria, consideration should be given to the practical aspects of protection, some of which have been discussed in this paper.

REFERENCES

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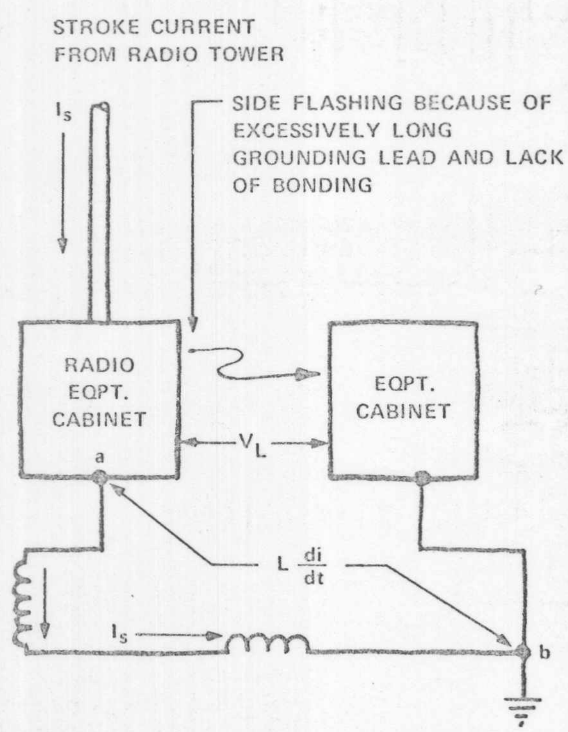

Fig. 1

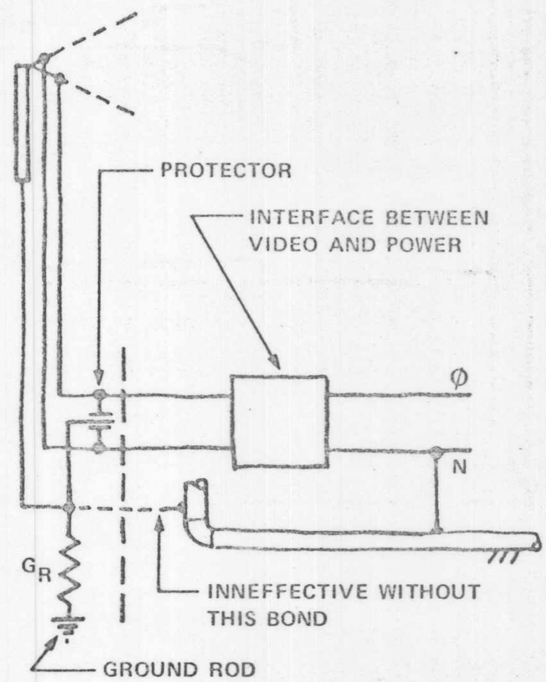

Fig. 2. Protection of TV receiver

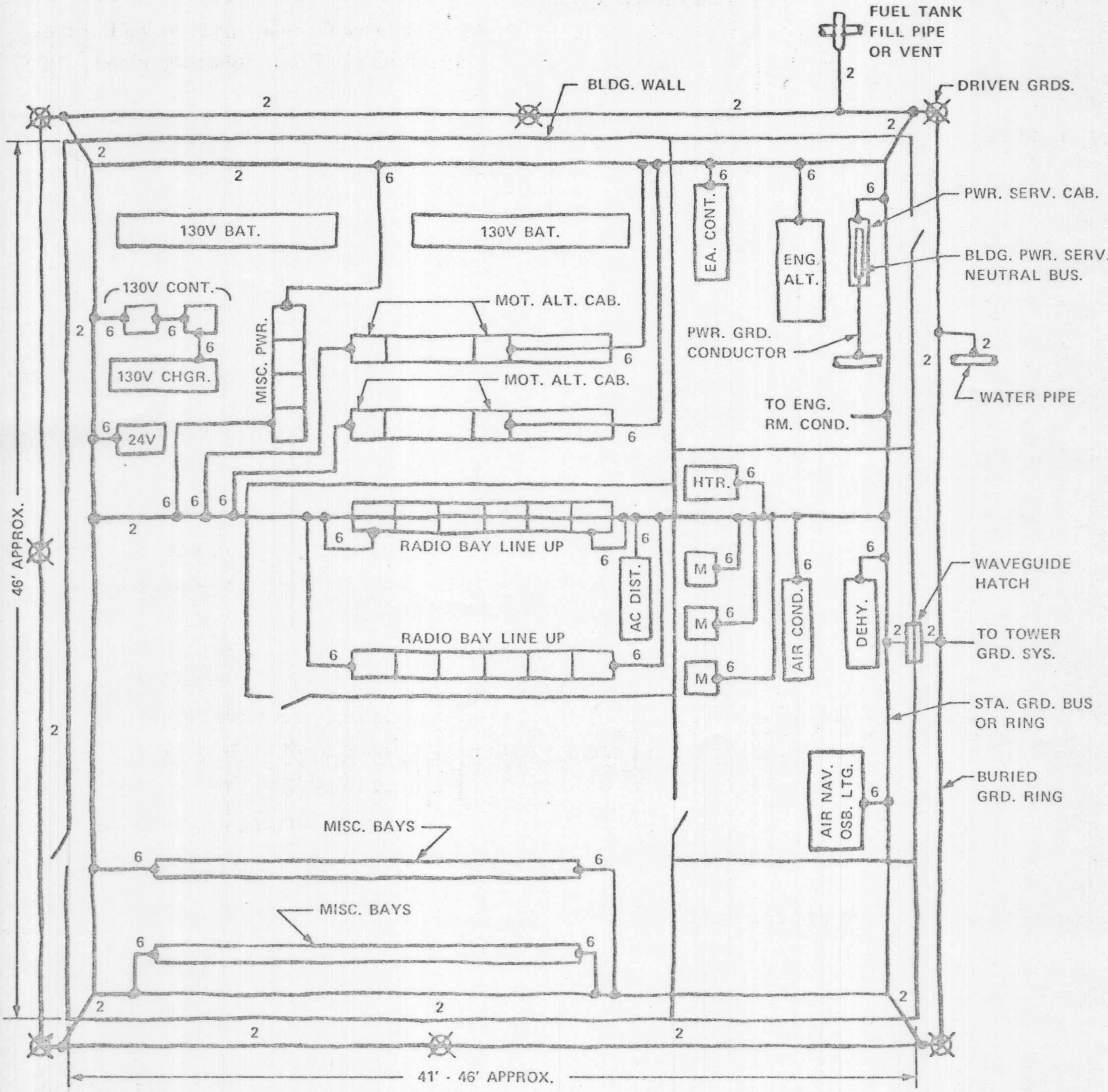

Fig. 3. Typical grounding and bonding arrangement at a microwave station (Numbers 2 and 6 indicate suggested AWG copper wire sizes)

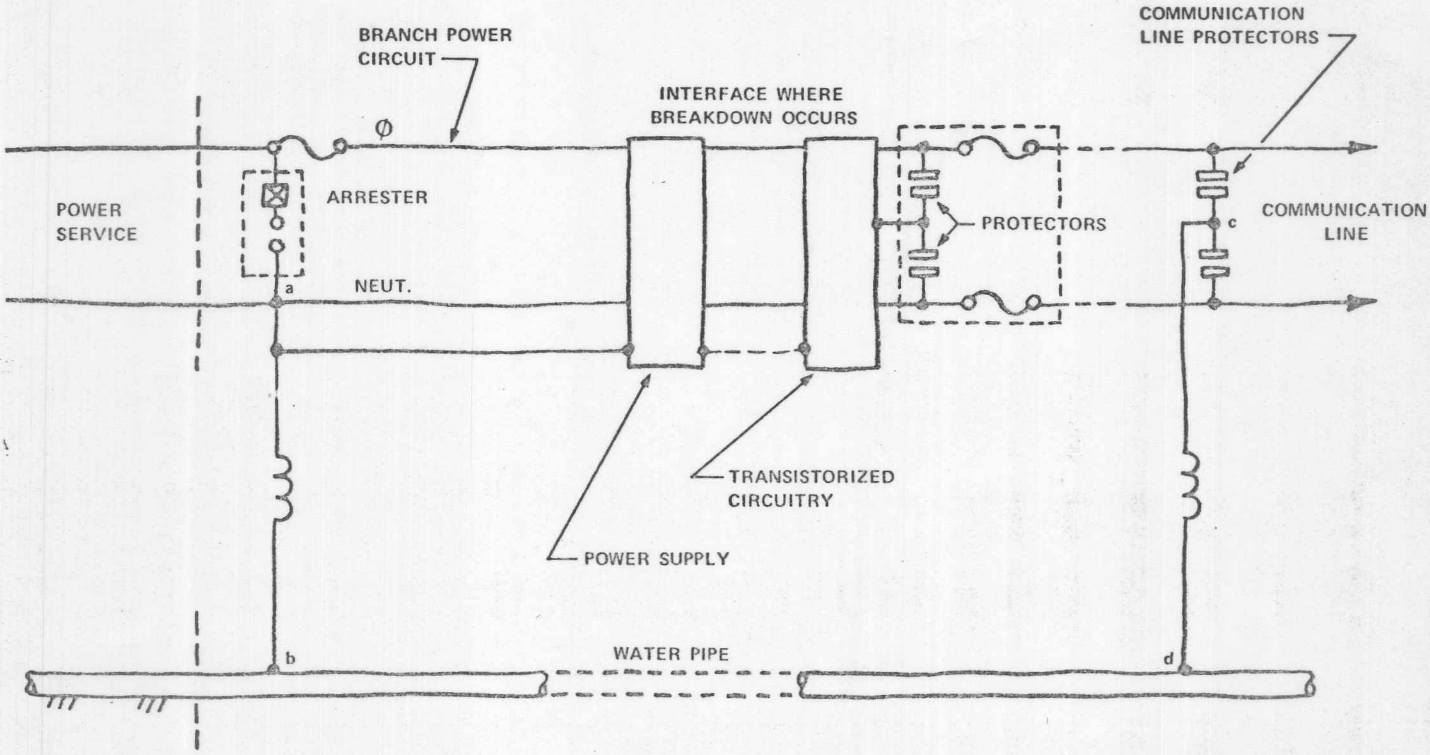

Fig. 4. Arrangement in which equipment circuitry is vulnerable to overvoltage surges from both communication and power lines. Remedial measures shown in dotted lines. Supplementary protection in equipment as required.